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Effects of stock collapse and management on price dynamics of blackspot seabream

Pascal Lorance *, Verena M. Trenkel

DECOD (Ecosystem Dynamics and Sustainability), IFREMER, INRAe, Institut-Agro - Agrocampus Ouest, France, BP 21105, Nantes Cedex 3 44311, France

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ABSTRACT

Stock collapse has profound impacts on ecosystems and fisheries, while the economic impacts have been less studied. The blackspot seabream stock collapsed in the early 1980s and has remain depleted since. The relationship between landings and prices was strongly negative during the decades spanning the collapse (1973–1990) and less during the low stock period with management measures (2003–2020). For other selected species, a significant negative relationship was only found for two species (out of 14) during the earlier period. In contrast, since 2003 prices decreased with landings for most species (10/17) irrespective of their characteristics and their management by a TAC or not. Short-term variations in blackspot seabream prices and landings were also negatively related during the collapse period, indicating rapid market adjustment to decreasing availability. In contrast, in recent years, short-term price variations were not linked to availability change, neither for blackspot seabream nor for most other species (10/17). The study reveals the strong unique effect the blackspot seabream collapse had on price. In the recent period, blackspot became the highest priced fish species in France, making the TAC management essential to limiting catches at sustainable level

1. Introduction

Fish stock collapses not only modify ecosystems, but have also important repercussions on dependent fisheries and fish markets. A well-known case is the collapse of the Newfoundland cod stock, resulting in major ecosystem changes [1,2] and impacting the whole seafood sector in the region [3]. The blackspot seabream (*Pagellus bogaraveo*) stock in the Bay of Biscay collapsed in the early 1980s due to overexploitation [4]. While management measures were put into place in 2003, the stock remains depleted [5]. Blackspot seabream is a protandric hermaphrodite [6,7], most individuals being first males and then developing into females. This particular reproductive biology explains the vulnerability of blackspot seabream to overexploitation, as not enough individuals will become females if fishing mortality is too high. While blackspot seabream stock dynamics in the Bay of Biscay has been studied [4], the economic impact of the collapse has not been investigated so far.

Fish auction (ex-vessel) sale prices have commonly been used as economic indicators [8–10]. The reaction of fish sale prices to changing landings has been studied empirically and theoretically. In several studies, fish sale prices have been found to decrease with increasing landed volume [11–13], though the opposite, that is higher landings and higher prices have also been reported [8]. A negative relationship between quantity sold and price is referred to as inverse demand system [11], which might occur on different temporal scales, from the daily [13, 14] to the annual level [15]. Fryxell, Hilborn, Bieg, Turgeon, Caskenette and McCann [15] identified a negative relationship between total annual landings and mean annual price of North American cod and pollock as the fishery degraded. In addition to a global negative relationship between prices and landed quantities found for many species, price changes in time have been found to be driven by temporal changes in landings [16].

Blackspot seabream is one of the higher priced demersal fish species in France, Spain and Portugal owing to its firm and flavourful flesh [17]. Until the mid-1970s, blackspot seabream was an abundant species in the Bay of Biscay [4] and available all year round on French fish markets. Since the stock collapse, international landings (Spain and France) of blackspot seabream from the Bay of Biscay (ICES Subarea 8) have declined from about 500 t in the mid-1990s to less than 100 t in 2022 [5] as stock recovery has not yet occurred. The size distribution of marketed blackspot seabream changed over time as a result of reduced consumer demand for portion-sized fish and legislation changes occurring in reaction to the stock collapse. Before the collapse, small blackspot

* Corresponding author.
E-mail address: pascal.lorance@ifremer.fr (P. Lorance).

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seabream (<100 g) were marketed [4] and individuals <500 g might have represented 20–24 % of the landings in 1966–1968 [18]. These small blackspot seabream were marketed under specific commercial names (pirono and pelon). In addition to changes in consumption habits increasing the body size of landed blackspot seabream in recent years, legislative measures have also modified the size composition of landings. In 2003, the first Total Allowable Catch (TAC) was set for the area stretching from west of Scotland to the Bay of Biscay (ICES subareas 6–8) to 350 tonnes in 2003 gradually reduced to 105 tonnes in 2020 applying the precautionary approach. The French quota has been 4 % of the TAC since 2003 (Council regulation (EC) No 2340/2002). However, the French landings are higher due to the quota exchange mechanism. Before 2003, only a minimum landing size was in place, set at 12 cm in 1983 and increased to 25 cm in 1986 (Council regulations (EEC) No 171/83 and 3094/96). These limits correspond to young-of-the-years and age 2 years respectively. A larger minimum landing size of 35 cm applied between 2010 and 2012. Since 2017, the species has been subject to a slightly smaller Minimum Conservation Reference Size (MCRS) of 33 cm (475 g) (regulation (EU) 2019/1241 of the European Parliament and of the Council). The minimum landing size in place before 2010 cannot be considered protecting a species changing sex from male to female around ages of 6–8 years and sizes of 30–35 cm [4, 19]. The 33 cm seems much more appropriate and it can be considered that there was no effective management of the species before 2003. In France, to the best of our knowledge, the species has always been sold as whole fresh fish. In recent years, the small quantities landed in French ports have been mostly sold to markets for high-quality products such as used by gourmet restaurants.

To investigate the economic consequences of the blackspot seabream stock collapse in the Bay of Biscay, this study analysed French blackspot seabream prices and their relationship with landings and compared them to those obtained for selected fish species fished in the same area. While French landings were only a proportion of total blackspot seabream landings, their time trend has closely followed the overall time trend [4]. The species selected for comparison were marine fishes, mostly demersal species, based on price and stock abundance criteria or taxonomic relatedness. The cross-species comparison provided broader insights into the relationship between landing changes and price changes and context for the rather unique blackspot seabream price dynamics.

2. Material and methods

2.1. Species selection

The price of blackspot seabream and its relationship with landings was compared to selected species caught by French fleets in the Bay of Biscay, Celtic Sea and English Channel, and which are mostly consumed fresh by households [20]. The list excluded all small pelagic fishes, for which a large proportion of landings goes through the fish processing industry, as well as lower value species, which may also be distributed through catering companies. For the comparison, three species categories were created: (1) the main benthic and demersal fish species in terms of landed value, referred to as **major species**: European hake *(Merluccius merluccius),* common sole *(Solea solea)* and two species of anglerfish sold together *(Lophius piscatorius* and *L. budegassa)*. (2) species fetching high prices, (≥ 5 €/kg in 2020), referred to as **high-value species,** including European seabass (*Dicentrarchus labrax*), John dory (*Zeus faber*), gilthead seabream (*Sparus aurata*), red porgy (*Pagrus pagrus*), and meagre (*Argyrosomus regius*), the two high price flatfishes turbot (*Scophtalmus maximus)* and brill (*S. rhombus*), pollack (*Pollachius pollachius*), and red mullet (*Mullus surmuletus*). Some of these species are of similar size than blackspot seabream whilst they also include the smaller red mullet and the much larger meagre. The large pelagic Atlantic bluefin tuna (*Thunnus thynnus*) was also included in high-value species. Only half of these high-value species are currently managed by a TAC (Table 1). (3) Species taxonomically related to the blackspot seabream, referred to as **related species**. These species included the axillary seabream (*Pagellus acarne*) of flesh quality similar to that of blackspot seabream but of smaller size, the lesser priced black seabream (*Spondyliosoma cantharus*) and white seabream (*Diplodus sargus*), and the common pandora (*Pagellus erythrinus*). The species in this group fetched lower prices (< 5 €/kg in 2020) and are not subject to a TAC. Though related to blackspot seabream, gilthead seabream and red porgy were included in the group of high-value species due their higher sale prices. However, they had the lowest landings in this group (Table 1). In addition to blackspot seabream, gilthead seabream, axillary seabream and white seabream are protandric hermaphrodites (Supplementary material S1), hence more vulnerable to overexploitation.

2.2. Data

To study the effect of the blackspot seabream collapse on prices, two periods were compared, during the collapse (1973–1990) and since management started (2003–2020) using two different data sources (Table 2). In the first data set, four species were missing or had to be removed due to species being combined (meagre, axillary seabream, common Pandora, red porgy, see Table 2). Further, for all species except Atlantic bluefin tuna and European hake, prices used in the first data set combined French northeast Atlantic and Mediterranean landings. However, landings of the studied species from the northeast Atlantic were much larger than landings from the Mediterranean, except for gilthead seabream, so that the mixed in Mediterranean Sea prices had little impact on most species. The second data contained only data from the northeast Atlantic and covered all studies species.

To investigate the potential effect of sale size category and fishing gear type on prices and verify that the results obtained with the two data sets described above were not biased by changes in the size of landed individuals, a third data set with landings and value landed per size category and fishing gear was used (Table 2). Suitable data were available from 2006 to 2020 only. When landed in the European Union, size categories of some of the studied species are defined by regulation (Council regulation (EC) No 2406/96 of 26 November 1996) and for other species French fish auction markets apply similar categories. Lastly, only combinations of species, size categories and fishing gear types which had data for all 15 years were retained for analysis.

For all data sets, mean annual prices were calculated as the sum of landed value divided by the sum of landings and inflation corrected to

Table 1
Mean French landings (t) from the northeast Atlantic and TAC management in place for selected species. Species groups: 1 major species; 2 high-value species; 3 related species.

Species	Group	TAC	Mean landings	
			1973–1990	2003–2020
Blackspot seabream*		2003-	1739	58
Anglerfish	1	Yes	15246	21191
Common sole	1	Yes	5210	7482
European hake	1	Yes	18245	26928
Atlantic bluefin tuna	2	Yes	447	583
Brill	2	Yes	301	519
European seabass	2	Yes	2023	4607
Gilthead seabream*	2	No	130	446
John dory	2	No	512	1656
Meagre	2	No		909
Pollack	2	Yes	5792	3190
Red mullet	2	Yes	1162	3051
Red porgy	2	No		33
Turbot	2	Yes	688	733
Axillary seabream*	3	No		51
Black seabream	3	No	2769	3507
Common pandora	3	No		
White seabream*	3	No	182	223

* protandric hermaphrodite (changing sex from first male to female)

Table 2
Description of data sets used for total landings and prices by species and year. ICES area corresponds FAO area 27.

Data set	Period	Area	Resolution	Species excluded from analysis	Source
1 collapse period	1973–1990	FAO area 27 (northeast Atlantic) and 37 (Mediterranean Sea) most species; FAO area 27 only for Atlantic bluefin tuna and hake	total landings and mean price	meagre (no data); axillary seabream, common Pandora and red porgy (combined data)	Steinmetz et al. (2008)
2 management period	2003–2020	ICES area French landings	total landings and mean price	None	French national database of fisheries statistics
3 detailed	2006–2020	ICES area French landings	Total landings[a] and mean price by gear type[b] and commercial size category	See supplementary material	French national database of fisheries statistics

[a] For species with only minor quantities of fish not landed as whole fish, these were excluded. For brill, pollack, anglerfish and European hake, which are mostly landed gutted, this presentation was retained. For common sole, turbot and John dory, both landings of whole and gutted fish were retained. All landed weights were converted to live weight.
[b] Gear types: hooks and lines, trawls and seines and other (various bottom nets).

2001 values using the consumer price index of French fresh food products extracted from the French institute for statistical and economical studies (www.insee.fr; value 100 in 2001).

2.3. Analyses

To investigate whether the decreasing time trend of blackspot seabream landings during the collapse period was shared with any of the other studies species, dynamic factor analysis (DFA) was used. DFA models explain multiple time series by a linear combination of common (hidden) trends (Supplementary material S2) [21]. Comparing common trend loadings among species can therefore provide insights into the specificity (or not) of the blackspot seabream landings time series.

The relationship between inflation corrected mean annual prices and total annual landings was then investigated at two time scales, during the two periods and interannually. The overall relationship between prices $P_{i,t}$ and landings $L_{i,t}$ for species i in year t during each time period was investigated using Pearson's correlation coefficient. The relative interannual variation in price $\Delta P_{i,t} = \frac{P_{i,t}-P_{i,t-1}}{P_{i,t-1}}$ was related to the relative interannual variation in landings; $\Delta L_{i,t} = \frac{L_{i,t}-L_{i,t-1}}{L_{i,t-1}}$ using linear regression.

We hypothesised that the price of the highly sought after blackspot seabream increased with decreasing landings (negative Pearson's correlation coefficient and slope of the linear relationship at the interannual scale) and expected a stronger link between price and landings during the collapse period in 1973–1990. Similarly, we expected Pearson's correlation coefficient and slope for most high-value species, except those subject to high aquaculture production, namely European seabass, gilthead seabream, meagre and turbot. These species have been produced by aquaculture in increasing quantities, which became larger than fisheries landings from the 1990s (Supplementary material S5). Aquaculture production of European countries of gilthead seabream and European seabass were more than 10 times those of fisheries catches during the 2010s. Aquaculture production of meagre is rapidly increasing, reaching about 5 times fisheries catches in EU countries recently. Further, for these four species, aquaculture from non-EU countries produced 2–10 times larger quantities than EU-countries aquaculture. This was expected to lead to fisheries landings not playing an important role in price formation as prices would have been driven by aquaculture production as observed in Australia in a similar situation [22]. In contrast, Atlantic bluefin tuna was produced by aquaculture in quantities similar to fisheries landings. As this species is highly sought after, we retained the assumption of a negative slope. For the three major species, we assumed demand being able to adjust to changes in landings, which means prices would have fluctuated independently of landings (b_i close to zero). Lastly, for the group of related species, we expected price also to be unrelated to landings, because they are of lesser flesh quality (black seabream, white seabream) or smaller size (axillary seabream, common pandora) and hence less demanded by consumers.

All calculations were carried out using the R programming language (version R-4.3.1). All tests were carried at 0.05 threshold value without adjustment for multiple testing, as we were interested in individual species results, not an overall test result. Tests were carried out using the R core package.

3. Results

Annual French landings during the collapse period (1973–1990) reflected the well-known rapid decrease of the blackspot seabream stock in the late 1970s (Fig. 1a). The landings time trend of blackspot seabream was not shared with any of the other studied species, as revealed by Dynamic Factor Analysis (Figure S2.1 in Supplementary Material S2). Two additional common time trends were identified by DFA for the other studied species (Figure S2.1). During the period with TACs (2003–2020), blackspot seabream landings first increased and then decreased again from the mid-2000s (Fig. 1b). Blackspot seabream had the highest loadings for the first common trend in DFA, with this common trend being shared by other species, including common sole, European seabass, meagre, pollack and black seabream (Figure S2.2). Further, DFA identified two additional common trends (Figure S2.2).

For blackspot seabream, the landings collapse led to an increase in prices right up to 1990 (0.47 € per year inflation corrected, Fig. 2). The prices of all other species varied less, with an increase for some high-value species (Fig. 2). Mean inflation corrected prices for blackspot seabream at the end of the collapse period in 1990 were similar to the prices fetched for the most valuable major species (common sole), while they remained average compared to the high-value species (Fig. 2). In contrast, at the end of the recent period with TAC management (2003–2020), the price fetched by blackspot seabream was higher than those of the highest priced species in the three considered species groups (Fig. 2). During this period, blackspot seabream prices continued to increase steadily at a reduced rate compared to the collapse period (0.33 € per year). This is however the strongest increase among all studied species for this period during which on average inflation corrected prices decreased slightly (mean −0.02 € per year). Prices increased for only four species (0.04–0.16 €/year), while they decreased for eight species (-0.46 to - 0.05 €/year). Since 2010, blackspot seabream has become the highest priced species landed by French vessels from the northeast Atlantic; most landings were caught in the Bay of Biscay. Blackspot seabream becoming the most expensive species is an important change from previous decades during which most of the species in the high-value group fetched higher prices than blackspot seabream.

For the collapse period, the strongest Pearson correlation between prices and landings was found for blackspot seabream (Fig. 3a). The correlation coefficient between landings and prices was negative for only two of the other species, while it was positive for three species (Fig. 3a; time series in Figure S3.1). Thus, these results did not provide any evidence in support of the group-specific hypotheses for landings-

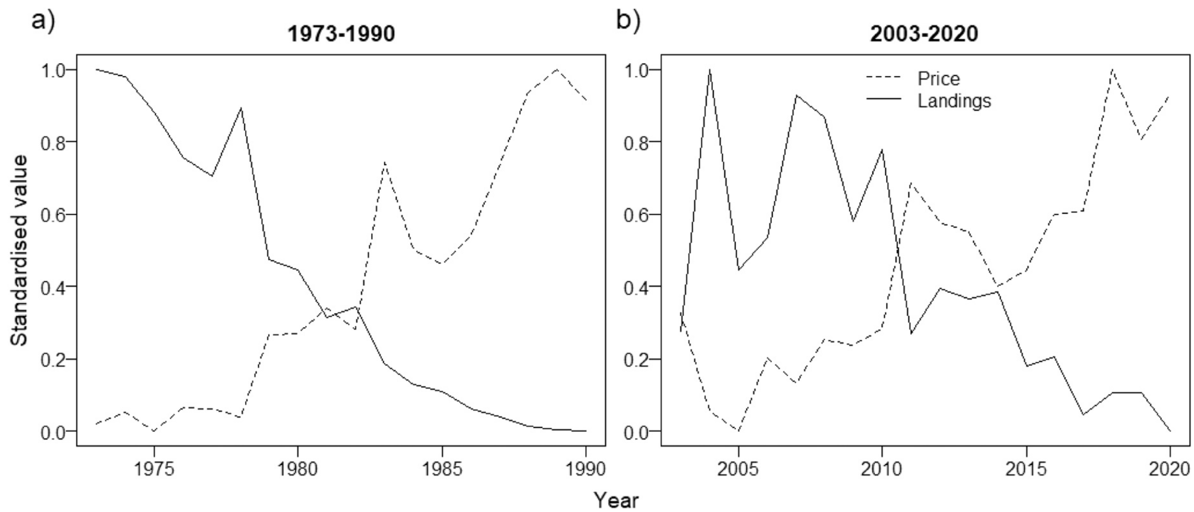

Fig. 1. Time series of standardised annual French landings and mean prices for blackspot seabream in the Bay of Biscay during the stock collapse (a) and since management measures were put into place (b).

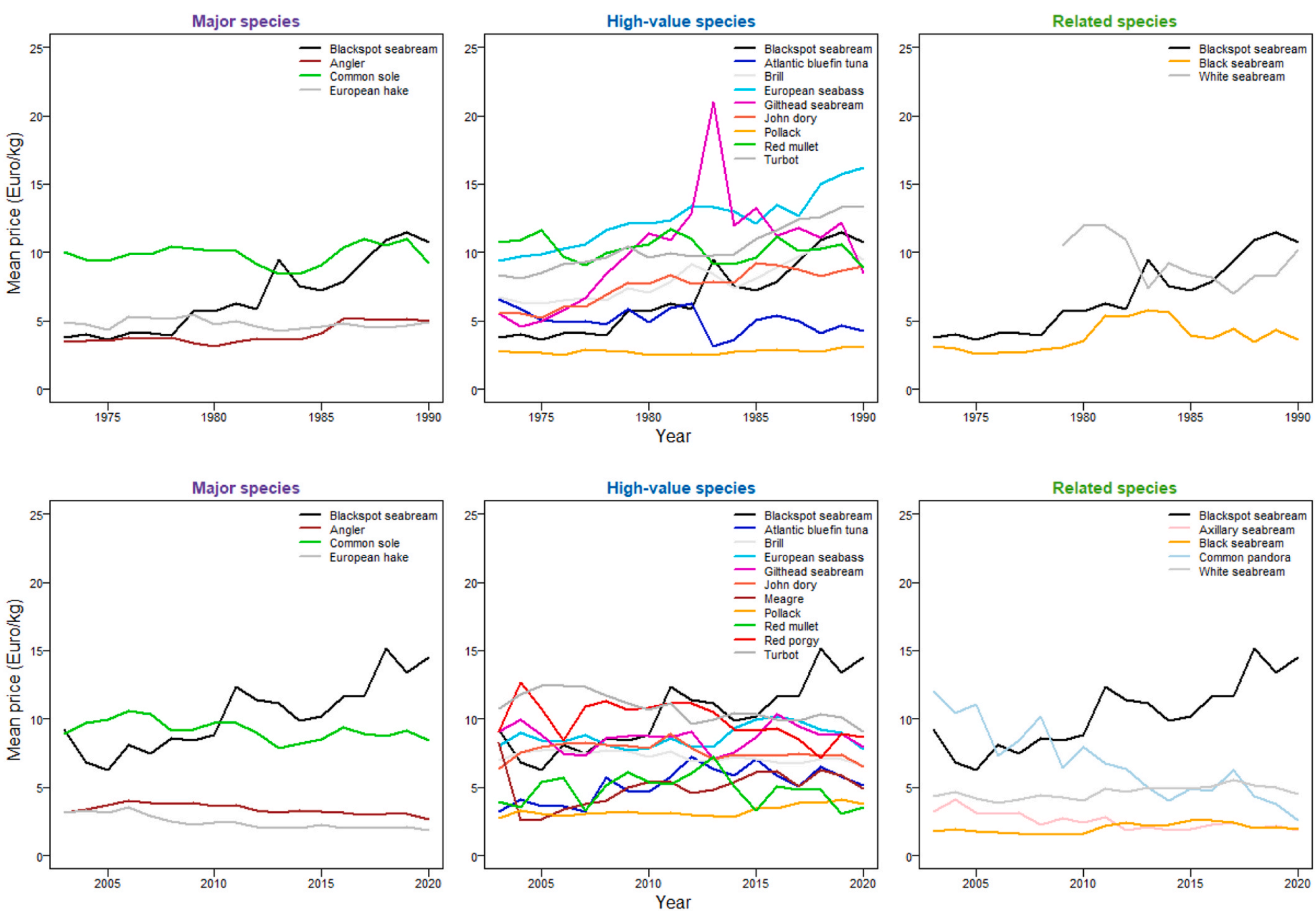

Fig. 2. Time series of mean inflation corrected prices for blackspot seabream and selected species from the Bay of Biscay for the blackspot seabream collapse period (1973–1990) and since management measures were put into place (2003–2020).

price relationships. For the period with TACs and low blackspot seabream landings, the correlation was significantly negative for blackspot seabream and most of the selected species (61 %), irrespective of group (Fig. 3b; time series in Figure S3.2). This provides evidence for landings generally having driven prices during this period and contradicts our hypotheses for major and related species, for which no relationship was hypothesized between landings and prices. For brill, the relationship was significantly positive for both periods (Fig. 3).

On the interannual scale, the negative slope of the linear relationship between interannual relative changes in prices and landings was steepest for blackspot seabream during the collapse period among all species and non-significant during the TAC period (Fig. 4). During the

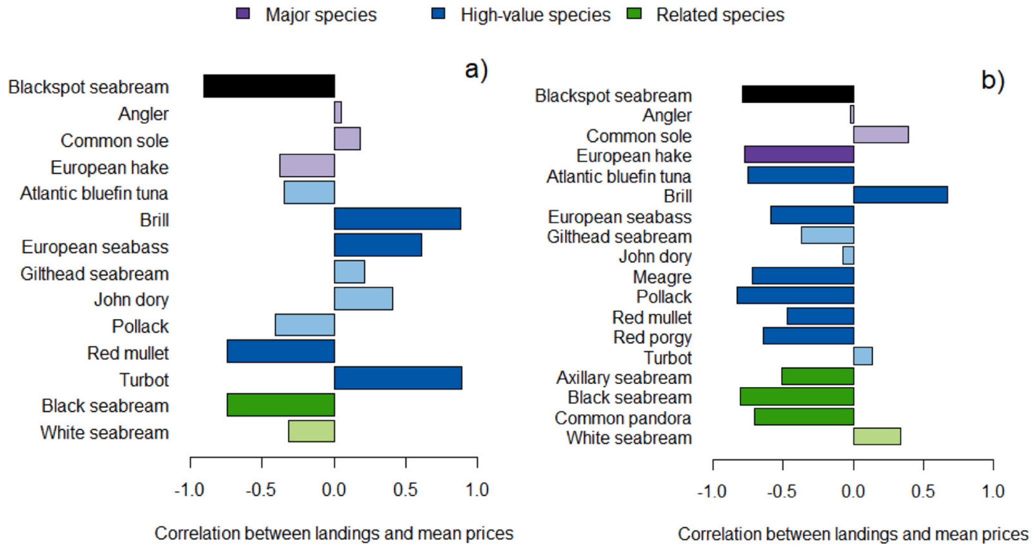

Fig. 3. Pearson correlation coefficients between landings and mean prices in the Bay of Biscay for blackspot seabream and selected species from three species groups. a) 1973–1990. b) 2003–2020. Significant correlations ($p<0.05$) in darker colour.

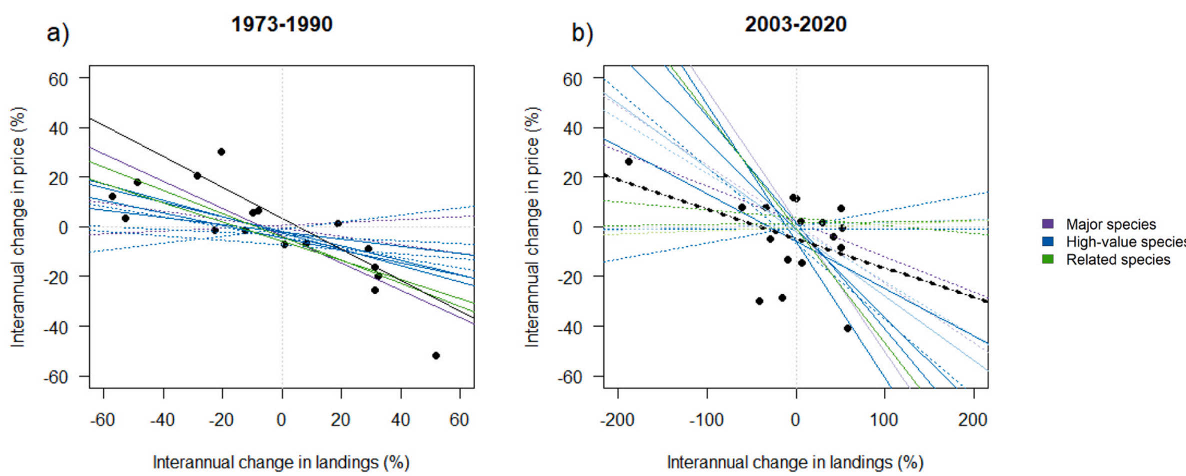

Fig. 4. Linear relationship between interannual changes in landings and prices for blackspot seabream (black) during the blackspot seabream collapse (a) and in a depleted state since management measures were put into place (b). Lines are fitted linear regressions for blackspot seabream and selected species colored by species group (see Table 1). Significant relationships have continuous lines; non-signifant relationships are represented as dotted lines.

collapse of blackspot seabream, a 1 % decrease in landings between years lead to a 0.62 % increase in price. During the collapse period, significant negative slopes were also found for eight (57 %) of the compared species and seven (39 %) between 2003 and 2020, with four species in common for the two periods, European seabass, pollack, red mullet and black seabream. During the TAC period, blackspot seabream prices did not follow interanual changes in landings (Fig. 4b). The strongest negative relationships were found for common sole, red mullet and black seabream, with again a smaller relative increase in price compared to landings (0.53 %, 0.55 %, 0.46 % increase in price for 1 % decrease in landings respectively.

To appraise the potential effect of size category and fishing gear type on results, the correlation between prices and landings was also calculated for combinations of species, gear and size categories for the period 2006–2020. Common pandora, axillary seabream and red porgy lacked sufficient data. For all considered species, price per size category was higher for hooks and lines than for trawls and seines; prices for the other gears were intermediate (Figs. 5, S4.2-S4.17). For the two largest size categories the price of blackspot seabream was about 10 euros/kg higher for landings from hooks and lines than for landings from trawls (Fig. 5). The correlations between prices and landings and the slope of the linear relationship between interannual relative changes in prices and landings were all negative, though only two of each were significant (Table S4.1). For hooks and lines, the price of the largest size category fetching higher price was not correlated with landings, which were stable over the period, while the price increased over time (Fig. 5). Thus, for blackspot seabream the overall (non-significant) negative relationship found for the TAC period was also present (and significant for 2 out of 8) by combinations of size category and gear type.

For the other species, out of the 159 correlations between prices and landings, 58 were significant, 52 (33 %) negative and 6 (4 %) positive (Table S4.1). Similarly, the slope for the linear relationship between interannual relative changes in prices and landings was significant for 50 out of 159 combinations (31 %), 46 out of 50 being negative (29 %). Significant negative correlations and slopes of the interannual relationship were found in similar proportions by species groups (high value, major and related), fishing gear and size category as well as between species subject to TAC management or not. Amongst high-value species, a similar proportion of significant and negative correlations and linear relationships was also found for species subject to high

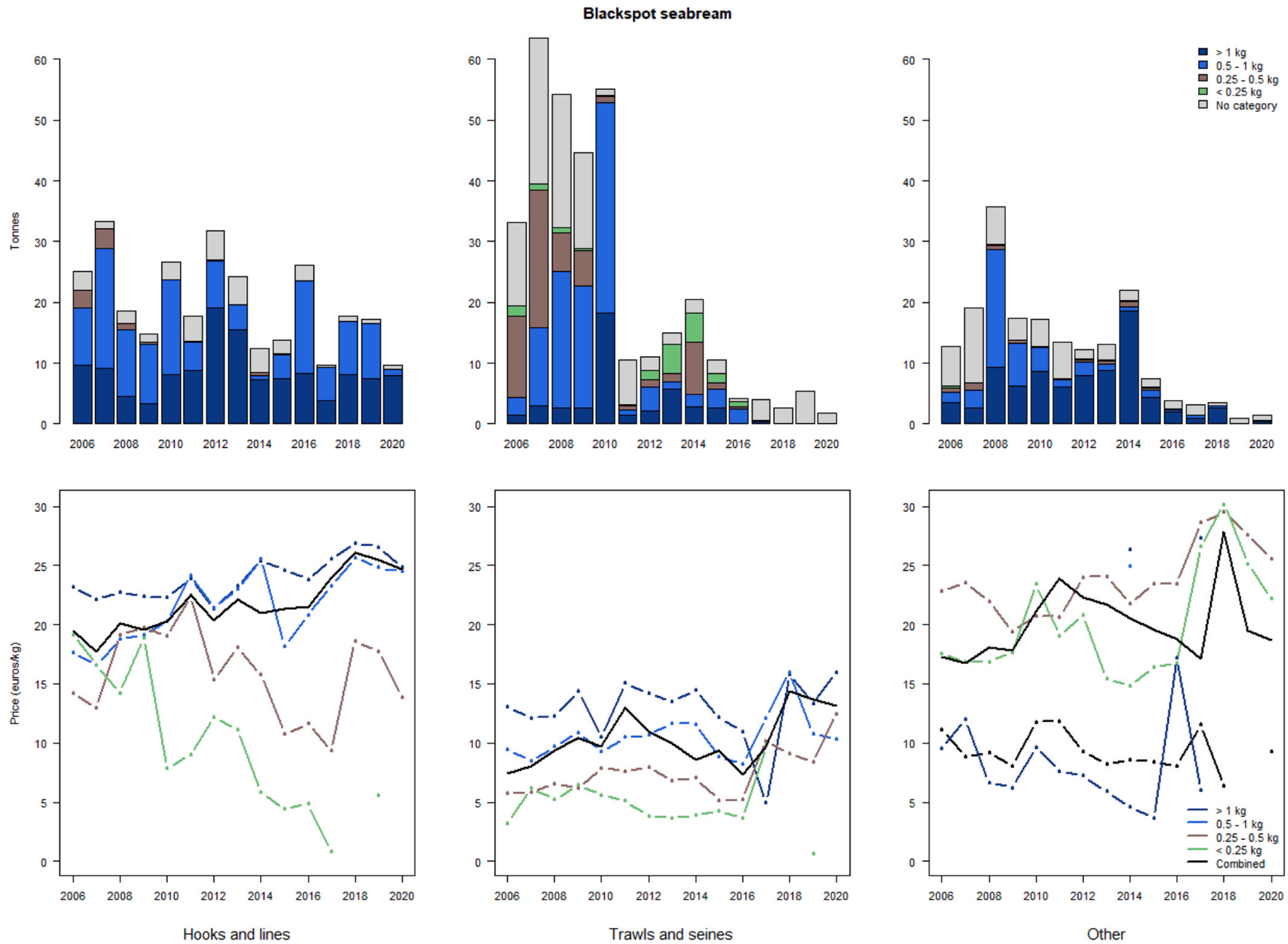

Fig. 5. Landings and mean price of blackspot seabream (*Pagellus bogaraveo*) per fishing gear and commercial category (2006–2020).

aquaculture production (Atlantic bluefin tuna, gilthead seabream, seabass, meagre and turbot) and the others.

4. Discussion

The collapse of once important stocks can profoundly affect fishing communities and the seafood sector [e.g. 3]. Nonetheless, the effect of the stock collapse on prices has seldom been studied, possibly because the collapse either concerned major stocks which were subject to international trade such as cod in the northwest Atlantic, or in the case of smaller stocks, suitable data may have been missing or fishing was subsequently banned. In the northeast Atlantic, in addition to blackspot seabream, landings declined strongly in the second half of the 20th century for several elasmobranch species, including angel shark (*Squatina squatina*), porbeagle (*Lamna nasus*) and white skate (*Rostroraja alba*) [23]. Catches of all three species have been prohibited since 2009. Further, price data of elasmobranch in the past are particularly unreliable because landings were mostly not reported by species. Thus, blackspot seabream offers a unique opportunity to study the effect of stock collapse on prices as the fishery remained open after the collapse and high quality data were available.

Overall, blackspot seabream sale prices were higher in years with lower landings as expected in an inverse demand system often observed for fish [e.g. 11] and bivalves [13]. This pattern was found both during the collapse period when landings decreased drastically and the more recent period with TAC management leading to more stable, though still decreasing landings. A negative relationship between prices and landings, though generally less strong, was only found for the most recent study period for the majority of species selected for comparison. For all species, the patterns were generally more marked when fishing gear and size category were considered. Further, the sign of the relationship did not depend on species group (major, high-value or related species). This later finding is in contradiction to our hypothesis for relationships differing by species groups. The lack of significant relationships for most species during the first study period might stem from the data being less reliable. Data from this historic period might have shown fluctuations which did not represent actual price variations. In particular, at the time, the same commercial name might have been used for different species, thus blurring any relationships between prices and landings. We tried to account for this by removing some species from the analysis, but the problem might have remained to some degree. However, the price-landings relationship for blackspot seabream seemed to have been strong enough not to have been masked by any potentially reduced data quality.

Blackspot seabream prices also increased interannually as landings decreased, though the relationship was only significant during the collapse period (1973–1990). During the recent period, a negative relationship appeared for two gear and size category combinations but the lack of relationship persisted for the six others. For around half of the other selected species, prices were found to increase between years when landings decreased during the first period, and for slightly fewer species during the recent period, independent of species group. These results provide thus only weak evidence for an inverse demand system operating in the French market for fresh fish also at the interannual scale, except during the collapse of blackspot seabream with a strong decrease in landings occurring simultaneously to an increase in prices.

A general inverse demand system, though not on the interannual scale, seems to apply to most species landed in French northeast Atlantic ports in recent decades irrespective of the three species groups considered (major, high price and related). Other characteristics did not seem to play a role either, for example whether the species is subject to aquaculture or not. This latter result is in line with previous findings for Spain, where no or limited substitutability was found between farmed and fishery caught common sole, turbot, meagre, European seabass and gilthead seabream [24]. For these four species the aquaculture production is much larger than fisheries landings. The same study concluded some market integration between wild and farmed blackspot seabream existed and noted this was unexpected with respect to the small aquaculture production. The study also reflected a more than 10 euros higher price for wild blackspot seabream. The aquaculture of blackspot seabream never exceeded 250 tonnes annually and declined in the 2010s, with no production reported in 2020 (Figure S5.1). Owing to the price difference between farmed and wild blackspot seabream, the cessation of the aquaculture production might not be the driver of the recent price increase of fisheries catches of this species.

The inverse demand system was found for different species, independent of the species being subject to a TAC or not. Among the studied species, eight were not subject to TACs (Table 1). For species with a TAC, a landings decrease and an associated price increase may be regarded as a consequence of fisheries and stock management because landings levels are capped by the management and disconnected from the short-term economic attractiveness of the species. For species not subject to TAC, the possibility exists that increasing price with decreasing abundance is an incentive to increase the targeting of the species to maintain revenues generated from fishing the species, especially if harvest cost does not increase [12]. This may have been the case for blackspot seabream before 2003, which because of its aggregative behaviour used to be caught by mid-water trawls and seines. Catching the species by these gears was therefore banned by the fisher's committee and the rule was integrated into the certification of one sardine fishery by purse seiners from 2010 to 2022 [25].

In recent years, blackspot seabream was among the few higher priced species landed in French northeast Atlantic ports. Until 2003, the decline in blackspot seabream stock abundance had a direct effect on reducing landings [4]. In more recent years, landings were constrained by TACs and hence most likely less directly linked to availability to fisheries. As the stock trend since 2003 is unknown, the variation of price during this period can be considered an effect of management on landings rather than directly driven by stock abundance as probably in the early period. Surprisingly, the inflation corrected price of blackspot seabream increased in recent years in a general context of overall stable or decreasing fish prices, considering all major commercial, high-value and taxonomically related demersal fish caught in the northeast Atlantic by French vessels. Although the contribution of hooks and lines to landings of the species increased, the analysis by fishing gear and size category confirmed this increasingly high price of the species in recent years. The top ranking position of blackspot seabream in recent years, whilst landing from hooks and lines remained rather stable, may be seen as a result of the restrictive TAC, which led fishing vessels using other gears to avoid landing it.

Given the lower data quality for the first study period, attempts to compare prices presented here with other price estimates were made. The Sea Around Us (SAU) project published reconstructed landings and prices [26]. Estimated landings of blackspot seabream for the Bay of Biscay from SAU were in the same range as landings reconstructed by Lorance [4] but prices were very different from those estimated here. This was expected because of the reconstruction process of prices used in the SAU project. For studies like this one, SAU project contributors recommended using data collected from the studied fisheries rather than SAU reconstructed data [27]. Similarly, the attempt to compare our data with those made available by the Food and Agricultural Organisation (FAO) [28] was not more successful, because numerous demersal species were attributed the same price in this database, while they clearly fetched very different prices in French Atlantic harbours.

Our results demonstrated the strong impact the blackspot seabream stock collapse had on prices, much stronger than observed when landings varied for any of the other species. This suggests, stock collapse can have profound economic consequences. More surprisingly, despite the low landings in recent years due to TAC management, prices and landings remained negatively correlated. The same negative relationship was found for other studied species, covering a broad range of prices and landed quantities, as well as stock dynamics, without any species characteristics nor species-specific management measures explaining the pattern. In recent years, blackspot seabream became the highest priced marine fish landed by French fleets from the Atlantic, which makes the TAC management essential to prevent unsustainable catch of this species.

In contrast to blackspot seabream, so far, none of the three studied species also changing sex from male to female have collapsed in the northeast Atlantic (gilthead seabream, axillary seabream, white seabream), although none is subject to a TAC. While gilthead seabream is also a high-value species, landings have always been relatively low, although higher in the recent period (Table 1, Figure S4.7). Depredation by this species generates loss in farmed bivalves and dedicated fishing has been suggested to reduce the loss [29]. There is anecdotal informations that this depredation has indeed increased in the past decade along the French coast. Therefore, the management of this species may not only aim at fishing it sustainably or achieving an objective such as the MSY (maximum sustainable yield) approach but also at a trade-off between fisheries exploitation and molluscs aquaculture sustainability. In this context, the long-term objective would be the conservation of ecophysiological properties and genetic diversity of wild populations of gilthead seabream while keeping their depredation of bivalves aquaculture at sustainable level. Such a management objective is however highly challenging, considering that the current exploitation level is unknown, and the framework for the suggested trade-off remains to be defined.

Though not available as farmed products, the low value of axillary seabream and white seabream might make the introduction of management measures less pressing. However, as landings of both species have increased in recent years (Figures S4.14, S4.17), their landings should be monitored to detect early signs of potential overexploitation and introduce management measures in time to avoid the fate of blackspot seabream.

Among the five other species with no TAC management, meagre, black seabream, red porgy and common Pandora showed negative relationships between landings and prices in the most recent study period (Fig. 3b). Only meagre and red porgy were considered high-value species and only meagre had sizeable catches (average 900 t). The need and practicality of management of these species in unclear. In the northeast Atlantic, TACs are the main management measures and are based on stock assessments. Stock assessment of meagre and red porgy do not exist at the moment and collecting suitable data may be challenging. In the absence of reliable stock assessments, the ICES protocols end up recommending reducing the catch to zero over time, which does not seem a desirable approach for all stocks without assessment. Which other management measures may be suitable to these species is a question to consider with respect to their biology, and spatio-temporal distribution of their fisheries.

Other blackspot seabream stocks occur in Azorean waters, to the West of the Iberian Peninsula, in the Strait of Gibraltar and in the Mediterranean Sea. These are subject to the same combination of high price and vulnerability to fisheries than the Bay of Biscay stock, which may result in unsustainable exploitation depending on the suitability and enforcement of management. Strikingly, the Strait of Gibraltar stock seems to have collapsed in recent years whilst the Azorean stock seems exploited sustainably [30,31]. The former stock straddles the Northeast Atlantic, the Mediterranean Sea, and the Central Eastern Atlantic with contrasting management regimes and the area of the latter is entirely in the northeast Atlantic. Whilst the analysis of the pros and cons of different management regimes is far beyond the scope of this paper, this underlines that for any given stock adopting a harmonized management approach notwithstanding which political boundaries it straddles is a priority.

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CRediT authorship contribution statement

Verena M. Trenkel: Writing – original draft, Visualization, Supervision, Software, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Pascal Lorance:** Writing – original draft, Visualization, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

none

Data availability

Original data are nominal and confidential. Aggregated data, landings and value by species and year will be made available on a repository

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2024.106315.

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